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16. ABSTRACT

The need for effective sludge management is continual and growing. In the United States, the quantity of municipal sludge produced annually has almost doubled since 1972. The U.S. EPA established an Agency Sludge Task Force in 1982. In 1983 one of the Task Force's major recommendations was to develop a comprehensive technical regulatory program under Section 405(d) of the Clean Water Act that requires the U.S. EPA to develop and issue regulations which (1) identify uses for sludge including disposal; (2) specify factors to be taken into account in determining the measures and practices applicable for each use or disposal (including costs); and (3) identify concentrations of pollutant which interfere with each use or disposal. The major areas discussed in this manuscript are; regulation development, incineration, selection of model plants, air dispersion modeling, most exposed individual, risk level, reference air concentration and an example calculation.

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Risk Assessment in Development of Municipal Sludge Incineration Regulations Under 405(d) of the Clean Water Act

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The need for effective sludge management is continual and growing. In the United States, the quantity of municipal sludge produced annually has almost doubled since 1972 when the U.S. Congress enacted the Clean Water Act (Public Law 92-500) which imposed uniform minimum treatment requirements for municipal wastewater. Municipalities currently generate approximately 6.9 million dry metric tons of wastewater sludge a year or approximately 29 kilograms per person per year. Currently, this Sludge is being managed as follows:

Landfilling - 40%
Land Application - 19%
Incineration - 20%
Ocean Dumping - 7%
Distribution and Marketing - 6%
Storage Lagoons and Other -6%
Other - 2%

In the early 1980's the U.S. Environmental Protection Agency (EPA) recognized that the authorities and regulations related to municipal sludge were fragmented and were not providing States and municipalities with adequate guidelines on which to base sludge management decisions. Based on this observation, an Agency Sludge Task Force was established in 1982 which was responsible for:

1) Assessing the magnitude and management approaches to municipal sludge reuse and disposal nationwide;

2) Evaluating the strengths and weaknesses of past regulatory activities; and

3) Identifying data and informational needs in order to direct EPA research in the field.

In 1983 the EPA Sludge Task Force presented its finding to the Agency. One of the major recommendations was to develop a comprehensive technical regulatory program under Section 405(d) of the Clean Water Act. Section 405 requires the U.S. EPA to develop and issue regulations which (1) identify uses for sludge including disposal; (2) specify factors to be taken into account in determining the measures and practices applicable for each use or disposal (including costs); and (3) identify concentrations of pollutant which interfere with each use or disposal.

REGULATION DEVELOPMENT

Many complex scientific and technical evaluations are necessary for the development of these regulations. The process has been divided into the following work elements:

1) identify pollutants of concern,
2) develop risk assessment methodologies,
3) derive criteria, application rates and management practices,
4) generate technical support documents,
5) develop and issue proposed regulations; and
6) issue final regulations.

The pollutants of concern were identified in a series of environmental profiles completed in 1985. These profiles were essentially a series of worst case, minirisk assessments which screened out sludge pollutants for each disposal option. The profiles evaluated 49 pollutants for four disposal options. The profiles work also identified the environmental pathways of concern for each of the options. The pathways for each

disposal option are listed in Table 1. The sludge pollutants identified for incineration in the profiles for further regulatory work are shown in Table 2.

A second effort recently completed is the development of detailed methodologies for quantifying the risk of a particular pollutant for a specific pathway. These methodologies are being used to derive maximum permissible pollutant levels in sludge and to define management practices for municipal sludge disposal. These methodologies are complex due to the number of environmental pathways which must be evaluated. The methodologies include extensive use of environmental models such as air dispersion models and groundwater contamination models. The methodology documents also set forth the assumption used and the limitation of each model.

To date the Agency has completed development of risk assessment methodologies for four reuse/ disposal options:

1) land application (including distribution and marketing),
2) landfilling,
3) ocean dumping, and
4) incineration.

These methodologies have been peer reviewed and assessed for technical adequacy by EPA's Science Advisiory Board.

The Agency is currently completing development of the draft regulations for the four disposal options. The regulations are being developed by a detailed evaluation of the pollutants identified in the profile using the risk assessment methodologies.

The Agency will also be proposing revisions to the Regulations for Processes to Significantly Reduce Pathogens and Processes to Further Reduce Pathogens currently found at 40 CFR Part 257. The Agency is developing a risk assessment methodology for exposure to pathogens in sludge. The methodology for pathogens will be used to evaluate all of the reuse/disposal options except incineration.

INCINERATION

The primary pathway being evaluated for sludge incineration is inhalation of incinerator air emissions. Three other pathways were considered and discounted. The pathway for ash disposal was eliminated from consideration because the ash is adequately controlled under the Resource Conservation and Recovery Act (RCRA). Furthermore, the scrubber water pathway was eliminated since the scrubber water is recycled into the front end of the wastewater treatment plant and is treated. The deposition of incinerator emissions, mainly particulates, is considered a potential pathway of concern, but presently methodologies to evaluate deposition and its impact on the environment and human health have not been fully developed. EPA will be evaluating deposition impacts in the future as models are refined.

SELECTION OF MODEL PLANTS

In order to evaluate health impacts of the emissions from incinerators a set of 10 sludge

incinerator plants were selected from an EPA sponsored telephone survey of sludge incinerators. The ten plants were carefully selected to represent a cross section of the 127 operational plants identified in the survey. Factors considered in selecting the plants were:

- Furnace type
- Sludge burning capacity
- Air pollution control systems type
- Stack heights
- Stack gas velocities
- Proximity of population to the facility
- Special terrain effects
- Potential for plume down wash
- Potential for adverse meterological effects

The selection of the 10 plants was reviewed by both an EPA work group and by an external peer review committee. Table 3 presents a summary of the relevant parameters for the ten modeled plants including the dispersion factor for the Most Exposed Individual expressed as the annual average ground level concentration (ug/m^3) per unit emission rate (kg/yr).

AIR DISPERSION MODELING

The air dispersion models used were EPA approved versions of Industrial Source Complex Long Term (ISCLT), LONG Z and COMPLEX I. These models were selected and used because of the following consideration:[1]

- ISCLT was utilized as the only EPA accepted model that considers the effect of building aerodynamic downwash. ISCLT however cannot handle complex terrain (terrain equal to or higher than the stack height).[2]

- LONGZ was used to supplement the ISCLT modeling results for the facilities which have complex terrain features in urban areas.[3]

- COMPLEX I was used to supplement ISCLT for complex terrain features in a rural setting.[3]

The results of the LONGZ and COMPLEX I supplemental modeling were merged with the ISCLT Modeling results to account for both the effects of downwash (which is very significant for most sludge incinerator facilities due to the predominance of very short stack heights above buildings) and the unusual terrain effects around many of the facilities.

EPA's human exposure model (HEM) was also run for all of the 127 facilities to determine the aggregate risk to the total population around each plant. An evaluation of the impact of emissions for both the Most Exposed Individual (MEI) modeling and Aggregate Modeling revealed that the MEI risks were higher. Thus use of the MEI concept was decided on as the more stringent health impact.

MOST EXPOSED INDIVIDUAL (MEI)

The potential health risk associated with the emissions from sludge incineration are related to the annual average ground level contaminant concentration. These annual average levels are determined from the Air Dispersion Model and used to calculate an equivalent lifetime dose and then are multiplied by the unit risk. The unit risk values for cancer risk were estimated based upon work completed by the U.S. EPA Carcinogen Assessment Group (CAG). The CAG risk assessments are based upon lifetime inhalation exposures for a 70 kilogram (KG) man inhaling 20 cubic meters (m^3) of air daily with 75% of the contaminant mass being absorbed into the body. The unit risk estimates developed by the CAG are defined as the lifetime cancer risk in a hypothetical population exposed continuously throughout their lifetime to a concentration of one pica-gram per cubic meter (pg/m^3) of a carcinogenic agent. This unit risk estimate can then be used directly to scale the risk associated with lifetime exposure rates which differ from 1 pg/m^3.

The exposure level for contaminant dose for an individiual residing in an area impacted by emissions from the municipal sludge incinerator depends upon the following:

- o Duration of exposure;
- o Inhalation volume;
- o Particle size distribution for incinerator emissions; and
- o Annual average contaminant concentrations.

Duration of Exposure

This includes consideration for the amount of time that the individual spends in a location impacted by the incinerator emissions. Also, the duration of exposure is effected by the percentage of time on an annual basis that the incinerator is operational and also reflects the expected operating life of the system.

For this analysis the most exposed individual (MEI) is assumed to reside in the area of maximum annual ground level concentration and is exposed 24 hours a day. The incinerator(s) will be assumed to be operational for the life of the individual (70 years) and be on-stream 100% of the time. The 70 year exposure is assumed valid since wastewater treatment plants are expected to be operated indefinitely into the future. The most exposed individual was chosen for this analysis because the MEI exposure is the most conservative scenario available.

Inhalation Volume

This refers to the volume of air inspired on a daily basis. A volume of 20 m^3 per day is assumed which is consistent with agency analysis and CAG calculations.

Particle Size Distribution

This refers to the size of the particulate emitted from the incinerator. For this analysis it is assumed that 100% of the inhaled particulate enters and is retained in the upper and lower respiratory tract. Any clearance of particulates from the upper respiratory tract results in particle ingestion.

Contaminant Concentration

Ambient concentrations are predicted in terms of an annual average in micro-grams per cubic meter ug/m^3. The human exposure is assumed to be 100% of the annual average which is consistent with assumptions for exposures calculated in other EPA studies.

RISK LEVEL

The selection of a carcinogen risk level for the MEI is a controversial subject. Risk levels for 1×10^{-3} up to 1×10^{-7} have been discussed and used in a number of regulatory decisions by EPA and others. 1×10^{-6} or the probability of one cancer case in a million has been considered by many as a conservative public health goal. The use of a 1×10^{-6} risk has also

been justified to account for the uncertainties and the assumptions typically used in risk calculations. In arriving at a risk level to be used in calculating emission rates or other environmental release rate, other factors such as the capability and costs of current and alternative waste management techniques are often used to modify stringent risk levels.

REFERENCE AIR CONCENTRATION

A reference air concentration (RAC, in mg/m^3) is defined as an ambient air concentration used to evaluate the potential for adverse effects on human health as a result of sludge incineration. That is, for a given incinerator site, and given the practice definitions and assumptions stated previously, the criterion is that sludge contaminant concentration which is calculated to result in air concentrations above the RAC would be a basis for concern that adverse health effects may occur in a human population in the site vicinity.

A RAC is determined based upon contaminant toxicity and air inhalation rate, from the following generalized equation:

$$\text{Reference Air Concentration: RAC } (mg/m^3) = I_p/I_a$$

where I_p is the acceptable pollutant intake rate (in m^3/day) based on the potential for health effects and I_a is the air inhalation rate (in m^3/day). This simplified equation assumes that the inhaled contaminant absorbed into the body through the lungs, at the same rate in humans as in the experi-same rate in humans as in the experimental species tested, or between routes of exposure (e.g., oral and inhalation). Also, this equation assumes that there are no other exposures of the contaminant from other sources, natural or manmade. I_p will vary according to the pollutant evaluated and to whether the pollutant acts according to a threshold or nonthreshold mechanism of toxicity.

EXAMPLE CALCULATION

After modeling is completed, the highest annual ground level concentrations can be identified at each of the ten sites. By using the maximum allowable ambient concentrations for the pollutants of concern, calculated from the RAC, the air modeling results can be used to calculate the stack emission rates for a given pollutant. This is done by simple ratios of the ambient concentrations and emission rates since the modeling results are linearly related.

The modeled emission rates for each plant may be compared with the actual emissions determined by the testing of sludge incinerators to determine whether the emissions are acceptable. If the RACs are exceeded, some type of criteria or management practice (or both) to reduce emissions will need to be developed.

This example calculation is for a carcinogen (chlordane) in sludge being incinerated at Facility 7 (see Table 3). The Facility 7 site is located in an urban, industrialized area. Three incinerator flue stacks at the facility are taller than the critical height where building aerodynamic downwash would be expected to increase near-source surface concentrations. The incinerator plant building is a complex structure with varying roof height.

Using the air dispersion model, the highest concentration from the facility (under normal operating conditions) is estimated to be 1.27×10^{-4} ug/m^3/kg/yr (from Table 1).

Equation 2 calculates the allowable concentration of chlordane in sludge:

$$SC = \frac{RAC \times CF_1 \times CF_2}{DP \times FE \times FR \times CF_2} \qquad \text{(Eq. 2)}$$

where:

- RAC = Reference air concentration (ug/m^3)
- CF_1 = Conversion factor (mg/kg)
- CF_2 = Conversion factor (hrs/yr)
- DP = Dispersion modeling parameter ($ug/m^3[kg/yr]^{-1}$)
- FE = Fraction emitted (unitless)
- FR = Feed rate (kg/hr dry weight)
- SC = Allowable sludge concentration (mg/kg, dry weight)

$$SC = \frac{2.17 \times 10^{-3}\ ug/m^3\ ug/m^3 \times 1 \times 10^6\ mg/kg}{1.27 \times 10^{-4}\ ug/m^3\ (kg/yr)^{-1} \times 0.05^{*} \times 2660\ kg/hr^{**} \times 8760\ hr/yr}$$

$$SC = 14.7\ mg/kg$$

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* The fraction emitted for this calculation assumes 95% destruction efficiency.

** The feed rate for Facility 7 is an assumption, based on the design capacity.

The results of this calculation means that the chlordane level in sludge must not exceed 14.6 mg/kg (ppm) dry basis in order to protect the health of the most exposed individual.

EPA is scheduled to propose regulation for all sludge management options in 1987. Following publication in the Federal Register, public hearings will be held in several locations throughout the U.S. Final regulations will be promulgated after EPA has considered all public comments and addressed any new technical questions raised during the comment period.

References

1. U.S. Environmental Protection Agency, "Guidelies on Air Quality Models, Revised Draft." EPA 450/2-78-027, Research Triangle Park, NC (1984).

2. U.S. Environmental Protection Agency, "Industrial Source Complex (ISC) Model User's Guide, Volumes I and II." EPA 450/479-030 and EPA 450/4-79-031 (1979).

3. U.S. Environmental Protection Agency, "User's Instructions for the SHORTZ and LONGZ Computer Programs, Volumes I and II." EPA 930/9-82-004A and B (1982).

Table 1
Environmental Pathways of Concern for Sludge Disposal Options

A. Land Application (including D&M)

1) Soil biota effects
2) Soil biota predator effects
3) Phytotoxicity
4) Animal ingestion of sludge-amended soils
5) Animal toxicity from plants grown
6) Pica child ingestion
7) Human toxicity from plants on sludge-amended soils
8) The plant to animal to human pathway
9) Soil to animal to human pathway
10) Air particulate and organic volatilization inhalation
11) Surface runoff
12) Groundwater contamination

B. Landfilling

1) Groundwater contamination
2) Volatilized organic inhalation

C. Incineration

1) Air emissions inhalation
2) Ash disposal to ground-water contamination
3) Scrubber water disposal
4) Particulate deposition

D. Ocean Dumping

1) Aquatic life toxicity
2) Seafood to human consumption
3) Aquatic life effects of sedimentation

Table 2
Pollutants for Sludge Incineration Regulation Development

Aldrin/Diekrin
Arsenic
Benzo (a) pyrene
Beryllium
Bis (2-ethyhexyl) phthalate
Cadmium
Carbon Tetrachloride
Chlordane
Chloroform
Chromium
Lead
Mercury
Nickel
PCB
Toxaphene
Vinyl Chloride

Table 3
Relevant Parameters for the Ten Modelled Sludge Incineration Facilities

Facility No.	Type Incin.	Number	Total Capacity (Dry tons/day)	Stack Height (m)	Stack Diameter (m)	Stack Temp °K	Stack Velocity (m/s)	Stack Flow (ACMS)	Land Use	Building Dimensions Height (m)	Length (m)	Width (m)	Dispersion Factor (DF) (1) $\frac{g/m^3}{kg/hr}$
1	MH	2	31.5	25.4	0.91	339	14.9	9.93	Urban	18.2	26.5	23.9	1.4×10^{-3}
2	Elect.	2	10.0	7.6	0.31	311	7.79	1.61	Rural	5.5	31.7	23.5	1.25×10^{-3}
3	FB	2	13.6	16.2	0.61	300	11.03	3.45	Rural	10.7	34.9	34.9	8.48×10^{-4}
4	MH	2	89.4	21.0	0.91	300	7.78	5.11	Urban	16.2	34.9	14.1	2.10×10^{-4}
5	MH	10	982	22.9 (1) 44.0	1.22	310 (1) 307	14.3 15.7	19.6 21.5	Urban	29	82.0	43.0	4.3×10^{-5}
6	MH	4	153.1	33.3	0.8	325	20	10.12	Urban	16.2	73.2	55.3	1.17×10^{-4}
7	MH	4	176.7	27.4	0.91	300	10.98	12.46	Urban	25.9	48.8	48.8	1.27×10^{-4}
8	MH	2	79.3	30.1	1.22	329	11.3	20.5	Urban	18.2	30.4	30.4	1.71×10^{-4}
9	MH	1	35.3	9.2	0.46	300	10.10	1.66	Urban	6.8	29.2	20.5	3.88×10^{-4}
10	FB	1	9.4	10.3	0.58	300	9.31	3.46	Rural	13.3	13.1	8.9	3.01×10^{-4}

(1) Two different incinerator facilities at one plant